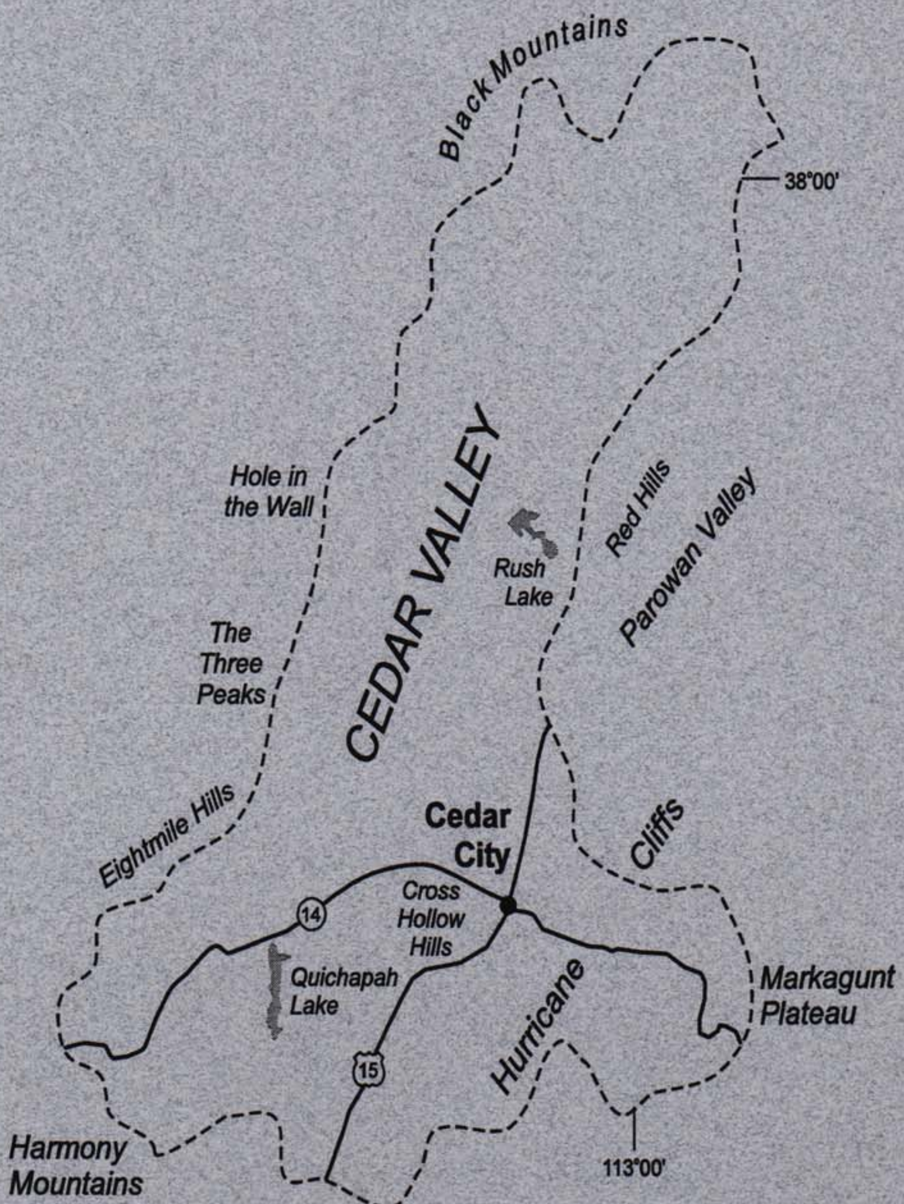
THE POTENTIAL IMPACT OF SEPTIC TANK SOIL-ABSORPTION SYSTEMS ON WATER QUALITY IN THE PRINCIPAL VALLEY-FILL AQUIFER, CEDAR VALLEY, IRON COUNTY, UTAH ASSESSMENT AND GUIDELINES

by
Janae Wallace and Mike Lowe
Utah Geological Survey



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ABSTRACT

Nitrate can be used to identify potential deleterious effects of development using septic tank soil-absorption systems. We use a mass-balance approach to provide a valley-wide assessment of the potential impact of nitrate from septic tank soil-absorption systems on ground-water quality. Approximately 1,406 septic systems exist in Cedar Valley. Our calculations indicate the number of septic tank soil-absorption systems in Cedar Valley should not exceed 4,000, representing a valley-wide average septic-system density of about 27 acres/system (0.109 km^2/system), to maintain an overall nitrate concentration of 6.5 ppm (6.5 mg/L). This allows a 1 mg/L degradation of water quality with respect to nitrate from the current background level of 5.5 ppm (5.5 mg/L). We also provide guidelines for site-specific evaluations of the effects of septic systems on ground-water quality for proposed subdivisions in Cedar Valley.

INTRODUCTION

Cedar Valley, Iron County (figure 1), is experiencing an increase in residential development. Most of this development, which uses septic tank soil-absorption systems for waste-water disposal, is on unconsolidated deposits of the principal valley-

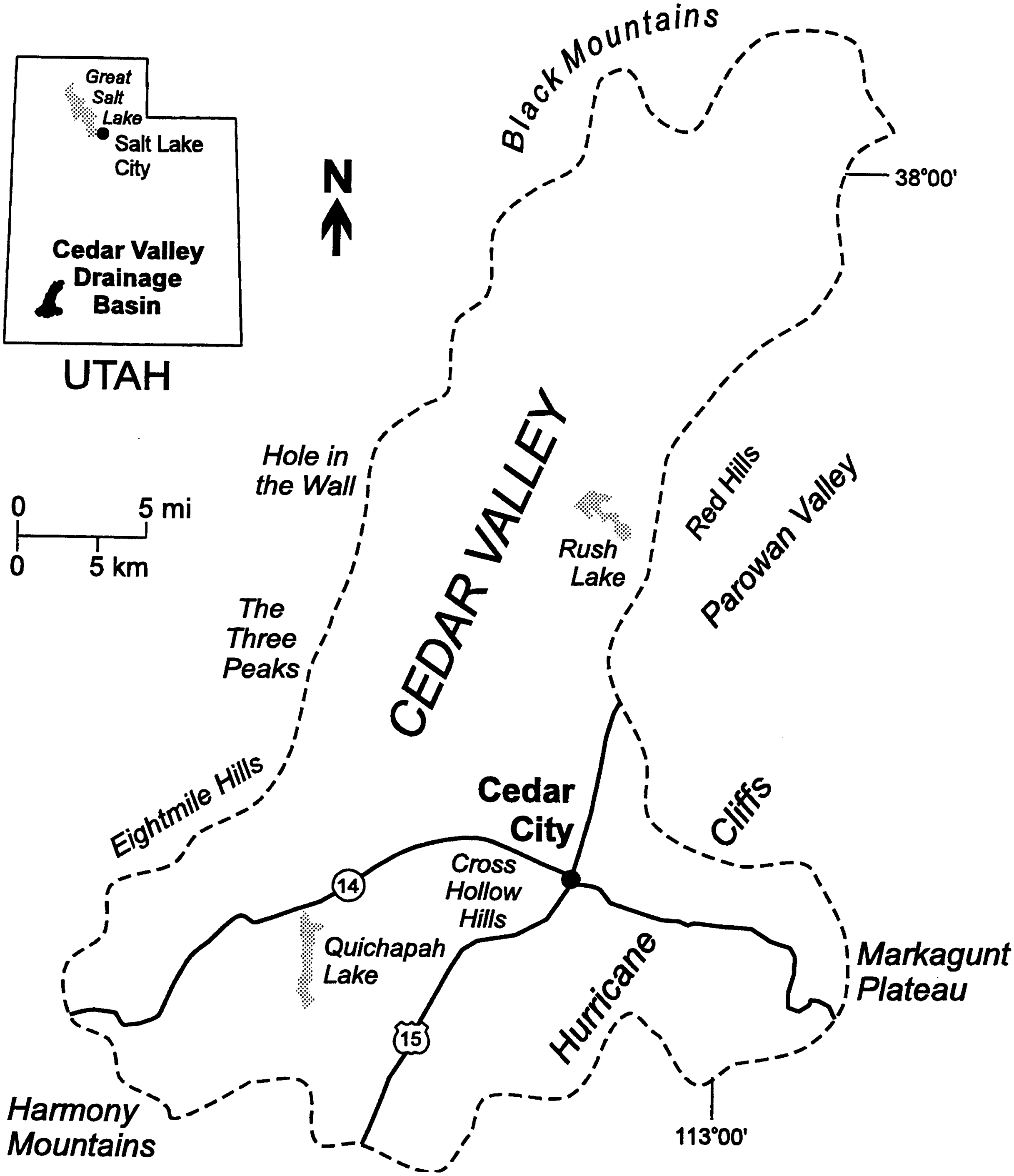

Figure 1. Location of study area.

fill aquifer. Ground water provides almost all of Cedar Valley's drinking-water supply. Preservation of ground-water quality and the potential for ground-water-quality degradation are critical issues which should be considered in determining the extent and nature of future development in Cedar Valley. Local government officials in Iron County have expressed concern about the potential impact that development may have on ground-water quality. This report was prepared as part of a ground-water-quality classification project funded by Cedar City, Enoch City, Iron County, Utah Division of Water Quality, Utah Division of Water Resources, and the Central Iron County Water Conservancy District.

Nitrate from sewers, septic tank soil-absorption systems, fertilizer, and other anthropogenic sources is a useful indicator of human impact on ground-water quality. Nitrate can thus be used to identify potential deleterious effects of development using septic tank soil-absorption systems. The purpose of this document is to: (1) provide a valley-wide assessment of the potential impact of nitrate from an increasing number of septic tank soil-absorption systems on ground water in Cedar Valley using methods similar to those used by Hansen, Allen, and Luce, Inc. (1994) for Heber and Round Valleys, Wasatch County, Utah; and (2) provide site-specific recommendations for evaluating the effects of septic systems on ground-water quality for proposed subdivisions in Cedar Valley. We use the methods of Hansen, Allen, and Luce, Inc. (1994) for valley-wide water-quality degradation assessments because they have been used in other Utah counties (Wasatch, Washington) for land-use planning purposes, and are easily applied and require limited data. We also provide guidelines for site-specific evaluations so that developers may hire ground-water consultants to evaluate specific subdivision sites for cases where valley-wide results do not meet their needs.

VALLEY-WIDE ASSESSMENT

Introduction

Most development in Cedar Valley uses septic tank soil-absorption systems for waste-water disposal. Ammonium from septic-tank effluent under aerobic conditions can convert to nitrate, contaminating ground water and posing potential health risks to humans (primarily very young infants). The U.S. Environmental Protection Agency ground-water-quality standard for nitrate is 10 ppm (10 mg/L). With continued growth and installation of septic tank soil-absorption systems in new developments, the potential for nitrate contamination will increase. One way to evaluate the potential impact of septic-tank systems on ground-water quality is to perform a mass-balance calculation using methodologies developed by Hansen, Allen, and Luce, Inc. (1994). This type of valley-wide analysis may be used as a gross model for evaluating the impact of proposed developments using septic-tank systems for waste-water disposal on ground-water quality and allow planners to more effectively determine appropriate average development densities (lot sizes).

Mass-Balance Approach

In the mass-balance approach of Hansen, Allen, and Luce, Inc. (1994) to compute projected nitrate concentrations, the nitrogen mass from projected new septic tanks is added to the existing, ambient mass of nitrogen in ground water and then diluted with the ground-water flow available for mixing, plus water that is added to the system by septic tanks. The method of Hansen, Allen, and Luce, Inc. (1994) estimates a discharge of 400 gallons (1,500 L) of effluent/day for a domestic home, and determines a best-estimate nitrogen loading of 40 ppm (40 mg/L) of effluent per domestic septic tank, with 80 ppm (80 mg/L) and 30 ppm (30 mg/L) per septic system as appropriate high and low values, respectively, for nitrogen loadings. Ground-water flow available for mixing is the difference between ground-water recharge and the sum of evapotranspiration and discharge to springs/seeps above the area of septic-system influence. The major control on nitrate concentration in aquifers using the Hansen, Allen, and Luce, Inc. (1994) approach is the amount of ground water available for mixing (Lowe and Wallace, 1997).

Results

Figure 2 shows a plot of projected nitrate concentration in Cedar Valley's aquifer versus septic-tank density and number of septic-tank units. Background concentration for Cedar Valley is 5.5 ppm (5.5 mg/L) (Conner and others, 1958; Joe Melling, Cedar

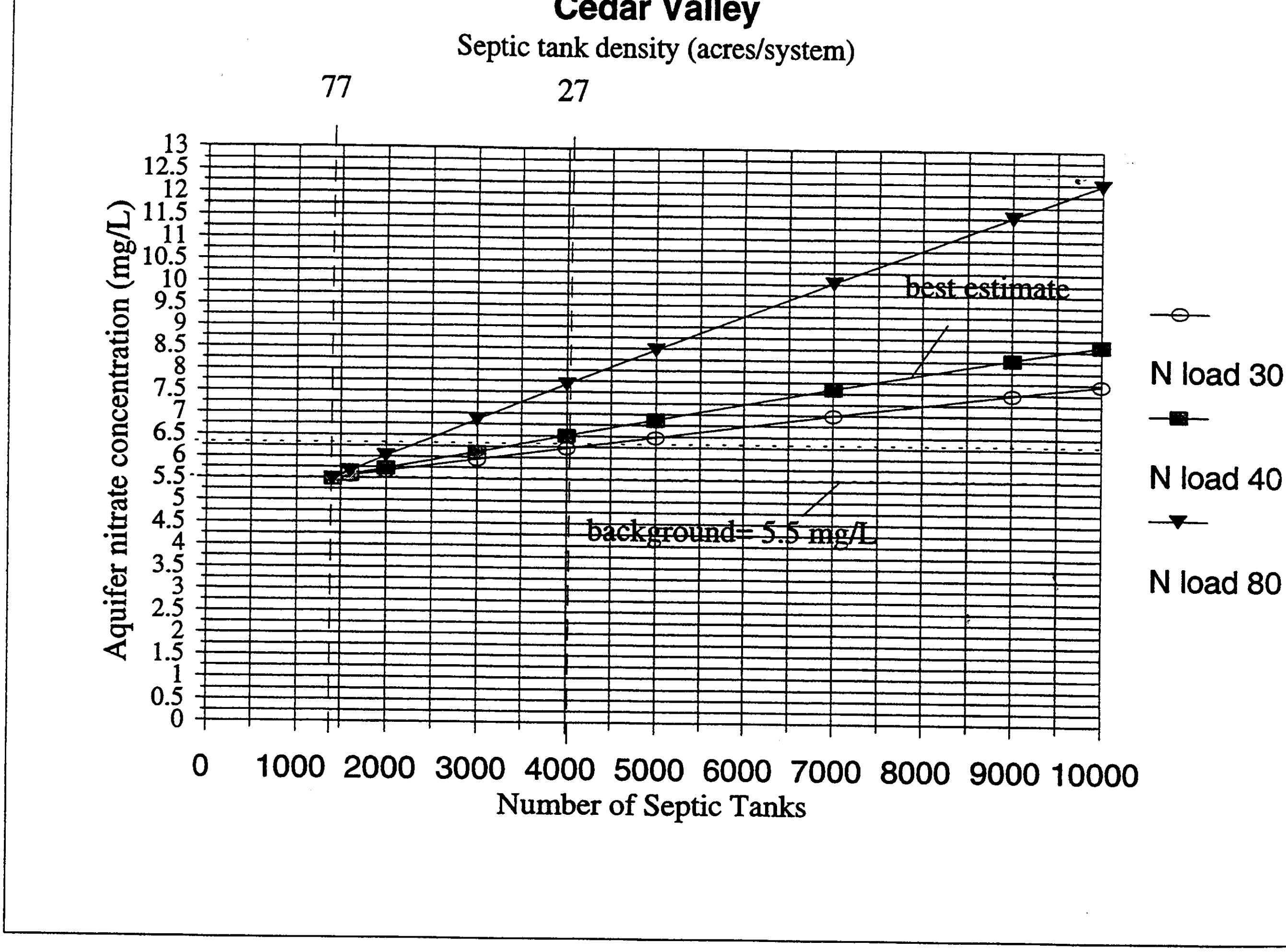

Figure 2. Graph showing projected septic-tank-system density versus nitrate concentration for the principal valley-fill aquifer in Cedar Valley. N load 30, N load 40, and N load 80 refer to the low, best-estimate, and high nitrogen loadings per liter of waste water from septic tanks (Hansen, Allen, and Luce, Inc., 1994).

City Manager, unpublished data, 1977-79; Quilter, 1996). Approximately 1,406 septic systems exist in Cedar Valley (Joe Melling, verbal communication, 1997). Cedar Valley has an area of approximately 108,800 acres (440 km^2), so the average septic-system density is about 77 acres/system (109 km^2/system). Based on Bjorklund and others' (1978) estimated hydrologic budget, ground-water flow available for mixing in Cedar Valley is 52.5 ft^3/s (1.49 m^3/s). For Cedar Valley to maintain an overall nitrate concentration of 6.5 ppm (6.5 mg/L) (which allows 1 mg/L of degradation, a value adopted by Wasatch County as an acceptable level of degradation), the number of new homes using septic tank soil-absorption systems should not exceed 2,600 based on the best-estimate nitrogen load of 40 ppm (40 mg/L) per septic-tank system (figure 2). This corresponds to a valley-wide total of 4,000 septic systems and an average septic-system density of about 27 acres/system (0.109 km^2/system).

Limitations to the Mass-Balance Approach

There are many limitations to this mass-balance approach.

1. Computations are typically based on a short-term hydrologic budget.

2. Background nitrate concentration is attributed to natural sources, agricultural practices, and septic-tank systems, but projected nitrate concentrations are for septic-tank systems only and do not include nitrate from other potential sources (such as lawn and garden fertilizer).

3. Calculations do not account for localized, high-concentration nitrate plumes associated with individual or clustered septic-tank systems.

4. The procedure assumes negligible denitrification.

5. The procedure assumes uniform, instantaneous ground-water mixing for the entire aquifer below the site.

6. Calculations do not account for pumping water wells.

7. Calculations are based on aquifer parameters for the entire valley (not specifically targeted to areas experiencing growth).

GUIDELINES FOR SITE-SPECIFIC SEPTIC-TANK-DENSITY STUDIES FOR PROPOSED SUBDIVISIONS

The guidelines outlined herein, describe one method for assessing site-specific impact of septic tank soil-absorption systems on ground-water quality for proposed subdivisions in Cedar Valley. The procedure uses a mass-balance approach similar to the analysis conducted by Hansen, Allen, and Luce, Inc. (1994) in Wasatch County and outlined above. The site-specific approach is subject to the limitations listed above, except calculations are based on site-specific rather than valley-wide estimates of aquifer parameters. This refinement of the valley-wide mass-balance approach provides a better understanding of the local effects on ground-water quality of development using septic-tank systems for waste-water disposal.

Site-specific evaluation of the effects of septic-tank systems on ground-water quality requires accurate determination of local aquifer parameters. Steps in the evaluation process include: (1) compiling existing topographic and geologic maps and driller's logs; (2) determining the ground-water-flow transect area (typically the subdivision area) and analyzing water-well driller's logs to determine the geologic characteristics, thickness, and extent of the aquifer; (3) determining the number of existing and proposed septic-tank systems in the area; (4) collecting samples for nitrate and analyzing data to identify background concentration; (5) measuring water levels from selected wells to determine hydraulic gradient and ground-water-flow direction; (6) selecting observation and pumping wells and conducting 24- to 100-hour aquifer tests to determine aquifer transmissivity values; and (7) calculating the projected site-specific nitrate concentration by applying the Hansen, Allen, and Luce, Inc. (1994) mass-balance approach using site-specific parameters obtained from steps 1 through 6 above to determine the existing nitrogen load and amount of ground water available for mixing. Ground water available for mixing (not including water in effluent) can be calculated using the following equation:

$$Q=TLI$$

where:

Q= volume of water in aquifer below subdivision available for mixing,

T= transmissivity,

L= length of flow through aquifer parallel to hydraulic gradient, and

I= hydraulic gradient.

Consultants' reports addressing site-specific effects of proposed developments using septic-tank systems for waste-water disposal and submitted to Iron County officials for approval should contain: (1) detailed topographic and geologic maps showing the location of all relevant features (property boundaries, septic-tank systems, water wells, and so forth), (2) water-well driller's logs used in the analysis, (3) laboratory data reporting nitrate concentrations, (4) static water-level measurements from wells, (5) tables reporting raw drawdown and recovery data from aquifer tests, (6) explanation of the methods/models used to interpret the aquifer-test data, and (7) all numbers (including conversion factors) and equations used to calculate results.

This site-specific evaluation process using the mass-balance approach can provide developers and Iron County officials with a defendable site-specific evaluation of acceptable septic-tank-system density for proposed subdivisions utilizing septic systems for waste-water disposal. The process also contributes to the protection of ground-water quality in areas experiencing rapid population growth.

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